EFFECTS OF SMOKING, USE OF ALUMINIUM UTENSILS, AND TAMARIND CONSUMPTION ON FLUOROSIS IN A FLUOROTIC VILLAGE OF ANDHRA PRADESH, INDIA

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SUMMARY: A field study was undertaken to determine effects of tamarind, the use of aluminium (Al) cooking utensils, and smoking on dental and skeletal fluorosis in the randomly selected fluoride (F) endemic village of Buttlapally in the Nalgonda District, Andhra Pradesh, India, where the F level in the drinking water is 3.6 ppm. In the survey, information on the above factors was collected for all persons in the village of 46 households (HHs) with a total population of 144 adults and 83 children. The survey revealed that persons who consume tamarind daily had significantly less ($p<0.01$) dental mottling, bamboo spine, and genu varum/genu valgum than occasional tamarind users. The incidence of skeletal and dental fluorosis was significantly higher among smokers than nonsmokers. About 95% of the HHs used Al utensils, which aggravated the fluorosis problem in the village. When the 3.6-ppm F water was stored undisturbed for 8 and 24 hr in an Al vessel, the F level decreased to 2.58 ppm and 2.36 ppm, respectively; boiling the water for 40 min in an Al utensil decreased the F level to 2.25 ppm. In conclusion, daily consumption of tamarind correlated with less dental and skeletal fluorosis, whereas smoking and the use of Al utensils for cooking appeared to enhance the effects of fluoride toxicity.

Keywords: Aluminium utensils; Andra Pradesh, India; Buttlapally, Nalgonda District; Dental fluorosis; Fluoride-aluminium interactions; Skeletal fluorosis; Smoking; Tamarind consumption.

INTRODUCTION

Earlier *in vitro,*[1] and *in vivo* studies conducted in dogs,[2] and humans[3] in this Institute as well as in rabbits[4] revealed beneficial effect of tamarind ingestion on fluoride (F) toxicity by way of increased urinary F excretion and decreased retention in bone when tamarind was ingested along with fluoridated water. However, there was no such impact in a F-endemic area, possibly due to other factors, such as use of aluminium (Al) utensils for cooking. When sour (acidic) foods are cooked in Al utensils in a fluoridated water medium, some Al leaches out, forming various complexes with F, such as AlF_4^-, AlF_3, and $AlF_2(OH)$, depending on the excess concentration of fluoride ions and on the pH of the solution. These can be transported more easily from the stomach into the blood stream and even across the blood-brain barrier than uncomplexed F ions.[5-8] The combination of F and Al modulates a growth factor dependent on the tyrosine kinase pathway, enhancing mitogen activated protein kinase and osteoblastic proliferation.[9] The present study was undertaken to determine the beneficial effect of daily tamarind consumption in a F-endemic area and to examine what effect the use of Al cooking utensils and smoking might have on fluorosis in the area.

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MATERIALS AND METHODS

Based on the data collected on drinking water quality by the district authority, the fluorotic village of Buttlapally in the Nalgonda District of Andhra Pradesh, India, with a reported 3.6 ppm F in the drinking water, was selected randomly for the study. The village is located 45 km from Hyderabad south of National Highway No. 9. The purpose of the study was explained to the people of the village, and information was collected by trained personnel concerning demographic features, duration of residence in the village, source of drinking water, dietary habits, consumption of tamarind, use of aluminium utensils for cooking, and smoking habits. Information on clinical manifestations such as dental mottling, bone deformities such as bamboo spine, neck rigidity, kyphosis, genu valgum/genu varum, anterior bowing, and bone fractures was collected with a pre-designed and pre-tested proforma survey of all 144 adults and 83 children available in all 46 households (HHs).

Collection of drinking water sample: Since there was only one source of drinking water in the selected village, the drinking water sample was collected in a 20-L plastic container to analyze the F content and to conduct *in vitro* experiments. The F level was estimated using a Model 940A Orion F-ion selective electrode meter (calibrated using TISAB and quality control samples before test samples were analyzed).

Urine collection and F analysis: Random spot urine samples (early morning first urine samples) were collected from 50 individuals (26 males; 24 females; between 6 and 72 years old) in clean 100-mL plastic container, adding 5–10 drops of toluene as preservative. The F level in the urine samples was estimated with the Orion F meter as with the drinking water samples.

In vitro study of Al-F complex formation:

(i) Effect of storage of fluoridated water in Al: One liter of water was stored in a used aluminum cooking vessel, and 20-mL samples were taken from it in plastic bottles at 1-hr intervals for 8 hr. A 24-hr sample was also collected from the stored water. The F level in the samples was then estimated with the F meter.

(ii) Effect of boiling fluoridated water in Al: One liter water was boiled in a used aluminum cooking vessel, and 20-mL samples were taken from the boiling water into plastic bottles after 10 and 40 min, and the F level in the samples was estimated.

(iii) Estimation of Al in the water before and after storage and boiling: The Al concentration was estimated using inductively coupled plasma mass spectrometry (ICP-MS with accuracy in ppb) at the National Geographical Research Institute, Hyderabad, India.

Diet survey: A semi-quantitative diet survey by the 24-hr recall method[10] was carried out in 10% of the households for calculating intake of proteins, carbohydrates, fats, calories, and calcium.

Statistical Analysis: Data were analyzed using SPSS (version 15), and the prevalence rates dental and skeletal fluorosis were calculated. The chi square test was used to detect any association between smoking, tamarind use, and signs and symptoms of fluorosis.

*Limitations of the study***:** Being exploratory in nature, the study involved only one fluorotic village.

RESULTS

As reported and confirmed here, the F level in drinking water of Buttlapally was 3.6 ppm. The prevalence of dental fluorosis (mottling) in the 6–14 year-old children was 43% among boys and 63% among girls. The effect of daily tamarind consumption on dental mottling, and symptoms of skeletal fluorosis is given in Figure 1. Daily tamarind users had a significantly ($p<0.01$) lower prevalence of dental mottling, bamboo spine, and genu valgum as compared to occasional tamarind users.

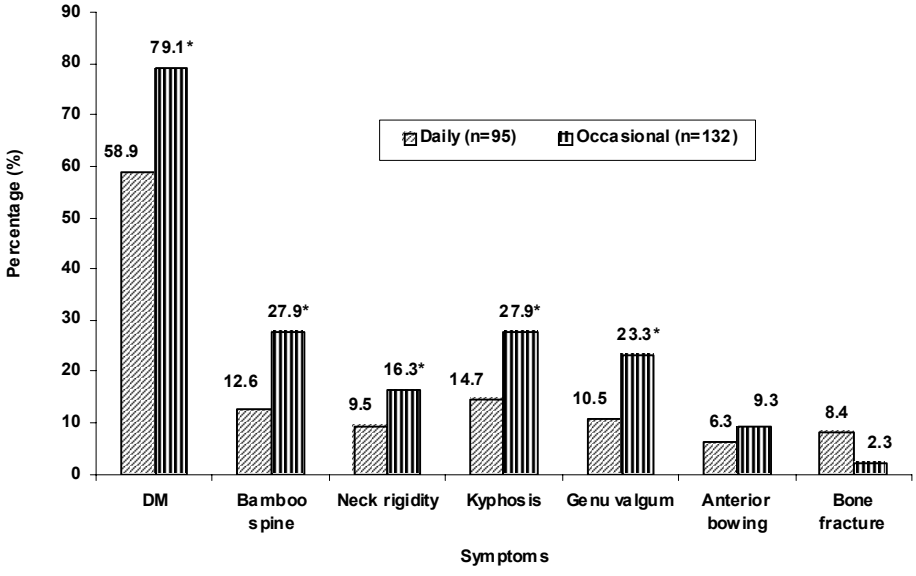

Figure 1. Prevalence (%) of dental mottling (DM) and skeletal fluorosis among tamarind users. *Significant by chi-square test at $p<0.05$.

The association of smoking with dental mottling, abdominal pain, and symptoms of skeletal fluorosis is shown in Figure 2. The prevalence of skeletal fluorosis was significantly ($p<0.01$) higher among smokers than nonsmokers.

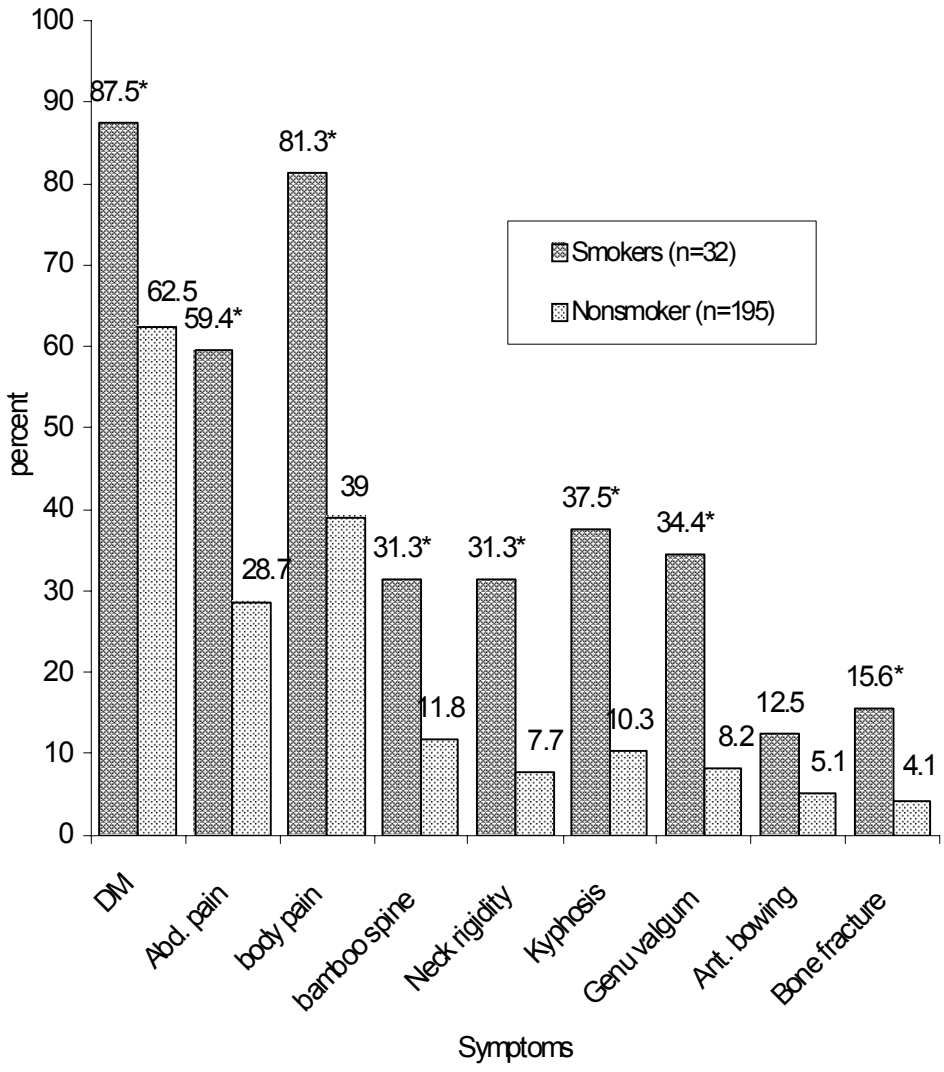

Figure 2. Prevalence (%) of dental fluorosis or mottling (DM) among smokers and nonsmokers. *Significant by chi-square test at $p<0.05$.

In-vitro study of F and Al in water: As seen in Table 1, the level of F and Al in the water decreased with time when the water was stored or boiled in a used Al cooking vessel.

Table 1. Effect of storage of F water in Al utensils.

Analyte	Initial value	Storage in Al utensil		Boiling in Al utensil
		After 8 hr	After 24 hr	After 40 min
Fluoride (ppm)	3.63	2.58	2.36	2.25
Aluminium (ppm)	1.21	1.10	0.64	0.29

Urinary F: The mean urinary excretion of F was higher (6.61±3.29 ppm) among daily tamarind consumers than occasional consumers (5.17±2.69 ppm).

Nutrient intake: The average daily intake of nutrients such as protein, carbohydrates, fat, calories, and calcium was calculated and reported in Table 2. The intake of all the nutrients was considerably below recommended levels.

Table 2. Nutrient intake of individuals in Buttlapally.

Survey Item No.	Nutrient	Intake/day	RDA[a]
1	Protein	44.04 g	60 g
2	Carbohydrates	336.6 g	460 g
3	Fat	22.3 g	40 g
4	Calories	1716 Kcal	2425 Kcal
5	Calcium	250.5 mg	1000 mg

[a]RDA = recommended dietary allowance.

DISCUSSION

Manifestations of fluorosis in this study with a similar level of F in the drinking water were highly variable. Among possible reasons for these variations may be differences in the nutritional status, calcium intake, tamarind and sorghum consumption, and smoking habit as well as the use of Al utensils for cooking and storing of water. Tamarind has been shown to exert a beneficial effect on F toxicity.[2-3] A recent study by Ranjan et al. revealed a decrease in plasma and bone F levels on ingestion of 100 mg tamarind water extract/kg bw.[4] In the present investigation, the prevalence of dental and skeletal fluorosis was lower among daily tamarind consumers than among occasional consumers. In addition, the use of Al utensils for cooking, storing, and drinking purposes appears to aggravate the problem. Leaching of Al occurs when F water is used for cooking or is stored in Al utensils,[11] and it forms AlF_x complexes, which are more absorbable in the intestine than F alone. These complexes inhibit H^+ATPase that is present in osteoclasts as well as in distal tubules of kidneys.[6-8] Inhibition of H^+ATPase in these distal tubules leads to more excretion of bicarbonate through urine, thereby causing metabolic acidosis, which is known to increase retention of F in the body due to formation of HF and also to promote osteoporosis and bone deformities. These effects may be the reason for more bone deformities in the present study. Also, the majority of the population belongs to the schedule caste, whose socioeconomic status is low and also use Al utensils for cooking and for storing of water.

Urinary fluoride always depends on drinking water F levels; however, spot urinary F samples will be higher[12,13] as compared to 24-hr urinary F. People in this study who consumed tamarind regularly exhibited fewer bone deformities, possibly due to more excretion of F through urine than occasional tamarind consumers, even though the food is cooked in Al utensils.[6-7] This finding indicates that tamarind probably plays a major role in decreasing bone deformities when compared to occasional tamarind users, the mechanism of which is not yet known.

Experiments *in vitro* revealed a decrease in both F and Al concentration in the water on storage and boiling, in agreement with earlier findings.[11] From these results, it can inferred that an alumino-fluoride complex may be an important factor causing fluorosis in poor families in fluorotic areas, which was also aggravated by smoking. Smoking triggers other bone-damaging changes, such as increased levels of the hormone cortisol, which leads to bone breakdown. Nicotine and free radicals present in tobacco are lethal to osteoblasts, the bone-forming cells.[14] Although this is only an exploratory study, the promising results obtained from it suggest that it would be desirable to plan and undertake a larger scale investigation involving a nonfluorotic village as a control.

In conclusion, apart from high F in drinking water as a cause of fluorosis, other factors such as the use of Al utensils for cooking and storing water, poor nutritional status, and smoking habit aggravate the problem of fluorosis in F endemic areas. However, the problem can be controlled to some extent by regular tamarind consumption, use of steel utensils in place of Al ones for cooking and for storing water, along with higher quality nutrition.

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